

STRENGTH OF SOFT CLAY REINFORCED WITH 16MM CRUSHED COCONUT SHELL COLUMN

FARHANIS AMIRAH BINTI ISMAIL

B. ENG (HONS.) CIVIL ENGINEERING
UNIVERSITI MALAYSIA PAHANG



SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor Degree of Civil Engineering.

(Supervisor's Signature)

Full Name : ASSOCIATE PROFESSOR DR. MUZAMIR BIN HASAN
Position : DIRECTOR OF CERRM/SENIOR LECTURER
Date : 31 MAY 2018



STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

(Student's Signature)

Full Name : FARHANIS AMIRAH BINTI ISMAIL

ID Number: AA14225

Date : 31 MAY 2018

STRENGTH OF SOFT CLAY REINFORCED WITH 16MM CRUSHED
COCONUT SHELL COLUMN

FARHANIS AMIRAH BINTI ISMAIL

Thesis submitted in fulfillment of the requirements
for the award of the
Bachelor Degree in Civil Engineering

Faculty of Civil Engineering and Earth Resources
UNIVERSITI MALAYSIA PAHANG

JUNE 2018

ACKNOWLEDGEMENTS

First and foremost, I would like to show my gratitude and thank to my supervisor, Dr. Muzamir Bin Hasan for his supervision, advice, guidance, encouragement and support in completing my research. His guidance helped me in all the time of research and writing of this thesis. I have been amazingly fortunate to have a supervisor who gave me the freedom to explore on my own, and at the same time the guidance to recover when my steps faltered.

In addition, I would like to give a big thank to Miss Haryani and Mrs. Ieszialiana for providing information, guidance and advice in assisting me to complete my Final Year Project. Also, sincere thanks to all the technician assistants of Soil & Geotechnical Engineering Laboratory, Faculty of Civil Engineering and Earth Resources, University Malaysia Pahang (UMP) for helping me in performing the laboratory works.

I would like to give a special thanks to my beloved partner, Nurrul Nisya Anuar who always working together with me to complete our Final Year Project and sincerely giving a free hand, ideas and suggestion regarding to my Final Year Project. Besides, I would like to take this opportunity to give my warmest thanks to all who have helping me with my work have collaborated the ideas to complete my thesis.

Lastly, I owe my loving thanks especially to my beloved mother Faridah binti Ismail, family and friends who always give me their supports, encouragement and pray for my success. Their understanding and encouragement gave me strength to concentrate on my studies and complete my Final Year Project on time.

ABSTRACT

Stone column could be used as a ground improvement technique where a portion of soft soil is replaced with granular material such as stone or sand. The benefit of using stone columns in low strength soil has been proved as an efficient method to improve bearing capacity and reduce settlement of soft soils. This study was aimed to investigate the improvement in shear strength of soft clay by embedded with single crushed coconut shell column. This paper was done by determine the height penetration ratio of a single crushed coconut shell column on shear strength characteristics. Unconfined Compression Test (UCT) was conducted for 4 batch kaolin samples including control sample in order to determine the shear strength. The research variable are diameter and height of crushed coconut shell column which under a concept of critical length of column. The increment of shear strength by embedded with crushed coconut shell column are 22.19%, 12.50% and 6.32% with 10.24% area replacement ratio at column penetration ratio of 0.60, 0.80 and 1.00 respectively. From the result obtained, the relationship of the increment of shear strength with the various column penetration show different pattern.

ABSTRAK

Medan batu boleh digunakan sebagai teknik pembaikan tanah di mana sebahagian tanah lembut diganti dengan butiran bahan seperti batu atau pasir. Manfaat menggunakan tiang batu di tanah yang kekuatannya rendah telah membuktikan sebagai satu kaedah yang berkesan untuk meningkatkan keupayaan galas lapisan dan mengurangkan penyelesaian tanah lembut. Tujuan kajian ini adalah untuk menyiasat peningkatan kekuatan ricih tanah liat lembut yang tertanam dengan bentuk satu pellet tiang tempurung kelapa hancur. Kajian ini telah dilakukan oleh menentukan kesan kawasan nisbah gantian dan nisbah penembusan lajur bentuk satu tempurung kelapa hancur mengenai ciri-ciri kekuatan ricih. Ujian Triaxial mampatan unconfined (UCT) telah dijalankan untuk sampel kaolin batch 4 termasuk sampel kawalan bagi menentukan kekuatan ricih. Pembolehubah kajian adalah garis pusat dan ketinggian tiang tempurung kelapa hancur yang di bawah konsep tempoh kritikal lajur. Kenaikan kekuatan ricih dengan tertanam dengan kolum tempurung kelapa hancur adalah 22.19%, 12.50% dan 6.32% dengan 10.24% kawasan penggantian nisbah dengan nisbah penembusan tiang 0.60, 0.80 dan 1.00 masing-masing. Daripada hasil yang diperolehi, keputusan yang didapati ada hubungan antara kenaikan kekuatan ricih dengan penembusan lajur pelbagai menunjukkan pola yang berbeza.

TABLE OF CONTENT**DECLARATION****TITLE PAGE****ACKNOWLEDGEMENTS** **ii****ABSTRACT** **iii****ABSTRAK** **iv****TABLE OF CONTENT** **v****LIST OF TABLES** **ix****LIST OF FIGURES** **xi****LIST OF SYMBOLS** **xiii****LIST OF ABBREVIATIONS** **xiv****CHAPTER 1 INTRODUCTION** **1**

1.1 Background of Study 1

1.2 Problem Statement 5

1.3 Objective 6

1.4 Scope of Study 6

1.5 Significant of Study 7

CHAPTER 2 LITERATURE REVIEW **9**

2.1 Introduction 9

2.2 Construction on Soft Soil 9

2.3 Soft Clay 12

2.3.1	Kaolin	13
2.3.2	Physical Properties of Kaolin	14
2.3.3	Compaction Test on Kaolin Clay	15
2.3.4	Unconfined Compressive Strength on Kaolin Clay	17
2.4	Coconut Shell	18
2.4.1	Physical Properties of Coconut Shell	22
2.4.2	Mechanical Properties of Coconut Shell	25
2.5	Ground Improvement	27
2.5.1	Stone Column	28
2.5.2	Past Researchers Work on Stone Column	29
2.5.3	Influence of Stone Column Length	30
CHAPTER 3 METHODOLOGY		33
3.1	Introduction	33
3.2	Selection of Ground Improvement Technique	33
3.3	Selection of Material	35
3.4	Sample Collection	35
3.5	Laboratory Works	35
3.5.1	Laboratory Work for Determination of Physical and Mechanical Properties	37
3.6	Reinforcing Soft Clay with Single Crushed Coconut Shell Column	45
3.6.1	Preparation of Samples	45

3.6.2	Installation of Crushed Coconut Shell Column	46
CHAPTER 4 RESULT AND DISCUSSION		48
4.1	Introduction	48
4.2	Summary of Kaolin and Crushed Coconut Shell	48
4.3	Physical Properties	50
4.3.1	Atterberg Limit Test	50
4.3.2	Relative Density	51
4.3.3	Specific Gravity	51
4.3.4	Particle Size Distribution	52
4.4	Mechanical Properties	54
4.4.1	Standard Proctor Compaction Test	54
4.4.2	Permeability	56
4.5	Shear Strength Analysis	57
4.5.1	Unconfined Compression Test	57
CHAPTER 5 CONCLUSION AND RECOMMENDATIONS		67
5.1	Conclusion	67
5.2	Recommendation	69
REFERENCES		71
APPENDIX		76
A	ATTERBERG LIMIT TEST	76

B	RELATIVE DENSITY TEST	78
C	SPECIFIC GRAVITY TEST	80
D	SPECIFIC GRAVITY TEST	81
E	HYDROMETER TEST RESULT	82
F	SIEVE ANALYSIS TEST	83
G	STANDARD COMPACTION TEST	84
H	STANDARD COMPACTION TEST	85
I	FALLING HEAD PERMEABILITY TEST	87
J	CONSTANT HEAD PERMEABILITY TEST	88
K	UCT (CONTROLLED SAMPLE)	89
L	UCT (60MM SAMPLE)	93
M	UCT (80MM SAMPLE)	97
N	UCT (100MM SAMPLE)	101

LIST OF TABLES

Table 2.1	Geotechnical forensic cases carried out by Public Work Department in 2010-2015	10
Table 2.2	Results of physical properties of kaolin from previous works	15
Table 2.3	Values of maximum dry densities (MDD) and optimum moisture contents (OMC) from previous works	17
Table 2.4	Results of UCS test from previous works	17
Table 2.5	Main coconut players in global market for 2005	19
Table 2.6	The values of optimum moisture content and maximum dry density	23
Table 2.7	Results of specific gravity from previous works	25
Table 2.8	Mechanical properties on various chemical composition	26
Table 2.9	Results for different column length	32
Table 3.1	A list of tests and standards used according to type of materials	36
Table 3.2	Dimensions of coconut shell column samples	47
Table 4.1	Summary of kaolin clay properties	49
Table 4.2	Summary of crushed coconut shell properties	49
Table 4.3	Comparison on the specific gravity of kaolinite from previous research works	51
Table 4.4	Comparison on the specific gravity of coconut shell from previous research works	52
Table 4.5	Comparison on the maximum dry density and optimum moisture content of kaolin S300 from previous research works	55
Table 4.6	Summary of analysis on Unconfined Compression Triaxial Test	57
Table 4.7	Average shear strength for controlled sample	58
Table 4.8	Average shear strength for embedded column of crushed coconut shell column with 60 mm height	59
Table 4.9	Average shear strength for embedded column of crushed coconut shell column with 80 mm height	60

Table 4.10	Average shear strength for embedded column of crushed coconut shell with 100 mm height	61
Table 4.11	Density of crushed coconut shell used in various dimension of columns	66

LIST OF FIGURES

Figure 1.1	Waste recovery through new technology	2
Figure 1.2	Coconut production in Asia Pacific region in 2014, by country (in thousand tons)	3
Figure 2.1	Sheet piles and piles adjacent to the excavation pit tilted	11
Figure 2.2	A large quantity of excavated earth dumped at the crest of excavation pit	12
Figure 2.3	Locality map of the kaolin deposits in Bidor Area	13
Figure 2.4	Graphical abstract of kaolin	14
Figure 2.5	Compaction curve	16
Figure 2.6	Compaction curve	16
Figure 2.7	UCS test on untreated kaolin clay and treated kaolin clay with lime	18
Figure 2.8	Agricultural consumption per capita 2013-2014	20
Figure 2.9	Grain size analysis of coconut shell powder passing 4.75mm sieve	22
Figure 2.10	Percentage of coconut shell powder against maximum dry density	23
Figure 2.11	Percentage of coconut shell powder against optimum moisture content	24
Figure 2.12	Effect of coconut shell ash (CSA) on maximum dry density and optimum moisture content	25
Figure 2.13	Mechanical properties of coconut shell composite	26
Figure 2.14	Influence of stone column length for difference column positions	31
Figure 3.1	Flowchart of research methodology	34
Figure 3.2	Mechanical sieve shaker	37
Figure 3.3	The condition of hydrometer in distilled water	38
Figure 3.4	Standard compaction test apparatus	39
Figure 3.5	Constant head permeability test apparatus	40
Figure 3.6	Relative density test apparatus	41
Figure 3.7	Specific gravity test apparatus	42
Figure 3.8	The apparatus use for unconfined compression test	44
Figure 3.9	Hole was drilled using 16 mm diameter drill bits	46
Figure 3.10	Top view of specimen	47

Figure 4.1	The location of kaolin S300 in the plasticity chart (ASTM D2487)	50
Figure 4.2	Particle size of distribution of kaolin S300	53
Figure 4.3	Particle size of distribution of crushed coconut shell	54
Figure 4.4	Graph compaction test of kaolin S300	55
Figure 4.5	Graph compaction test of crushed coconut shell	56
Figure 4.6	Shear strength for controlled samples	58
Figure 4.7	Shear strength for embedded crushed coconut shell column with 60 mm height	59
Figure 4.8	Shear Strength for embedded column of crushed coconut shell with 80 mm height	60
Figure 4.9	Shear strength for embedded column of crushed coconut shell column 100 mm height	61
Figure 4.10	Improvement of shear strength versus height of column / diameter of column	63
Figure 4.11	Relationship of strain and stress for embedded column of diameter with 60 mm height and 80mm height	64
Figure 4.12	Relationship of strain and stress for embedded column of diameter with 60 mm height and 100mm height	64
Figure 4.13	Relationship of strain and stress for embedded column of diameter with 80 mm height and 100mm height	65

LIST OF SYMBOLS

A_c	Area of a column
A_s	Area of a sample
H_c	Height of a column
H_s	Height of a sample
V_c	Volumes of a column
V_s	Volumes of a sample
D_c	Diameter of a column
S_i	Immediate settlement
S_c	Primary consolidation
τ	Shear strength of the soil
σ	Effective normal stress
W_L	Liquid limit
W_p	Plastic limit
I_p	Plastic Index
W_{opt}	Optimum water content
q_u	Deviator stress
S_u	Undrained shear stress
ΔS_u	Improvement undrained shear strength
ρ_d	Dry density
R^2	Correlation cohesion

LIST OF ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society of Testing Material
BS	British Standard
BSCS	British Soil Classification System
CS	Coconut Shell
CSA	Coconut Shell Ash
EDS	Energy Dispersive Spectrometry
EPF	Employee Provided Fund
FHWA	Federal Highway Administration
MIT	Massachusetts Institute of Technology
ML	Low Plasticity Silt
USCS	Unified Soil Classification System
USDA	US Department of Agriculture
WV	West Virginia

CHAPTER 1

INTRODUCTION

1.1 Background

Solid waste is one of the three major environmental problems in Malaysia. It plays a significant role in the ability of Nature to sustain life within its capacity. In 2013, a study by government showed the average Malaysian produced 800 gram of solid waste a day according to Ismail (2014). People living in urban areas produced 1.25kg of waste a day thus this led to an estimated 30,000 to 33,000 tonnes of waste being produced a day in 2013 compared to 22,000 tonnes of solid waste produced daily in 2012. Deputy Urban Wellbeing, Housing and Local Government Minister, Datuk Halimah Mohd Sadique said in 'The Malay Mail', the ministry viewed this as a major problem because the latest figure exceeded the government's projected waste production of 30,000 tonnes daily by 2020.

Sreenivasan & Govindan (2012) said that the amount of waste generated continues to increase due to the increasing population and development, and only less than 5% of the waste is being recycled. Despite the massive amount and complexity of waste produced, the standards of waste management in Malaysia are still poor. These include outdated and poor documentation of waste generation rates and its composition, inefficient storage and collection systems, disposal of municipal wastes with toxic and hazardous waste, indiscriminate disposal or dumping of wastes and inefficient utilization of disposal site space. In order to overcome this problem, our Prime Minister, Datuk Seri Najib Razak announced that Malaysia towards a clean and sustainable nation in 11th Malaysia Plan (Pauzee, 2016). "Achieving growth that is inclusive, sustainable, growth with equity, competitive and progressive" said Datuk Seri Najib Razak. Furthermore, in 11th Malaysia Plan, strategic thrusts number six are pursuing green growth for sustainability and resilient which are more focus to adopting the sustainable consumption

and production by managing waste holistically through better coordination, encouraging reuse reduce recycle (3R) and using waste as resources for industries. In major transformation initiative number four is the waste technology utilization for effective services and recovery. Figure 1.1 shows the waste recovery through new technology.



Figure 1.1 : Waste recovery through new technology

Source : Pauzee (2016)

Referred in Figure 1.1, organic waste facilities were included, thus organic waste can be used in engineering industries for sustainable construction. One of the organic materials used are coconut. Coconuts are known for their great versatility, as evidenced by many traditional uses, ranging from food to cosmetics. The use of coconut by-products has been a long time source of income for some people in the country (Ganiron, 2013). In Malaysia, coconut is one of the fruit crops which produce the highest amount of consumption per capita, therefore increasing the amount of waste material from coconuts. Coconut fiber and coconut shell are organic waste products obtained in the processing of coconut oil and coconut milk which are available in large quantities in the tropical regions of the world, most especially in Africa, Asia and America (Achaw, 2008). The coconut has many uses. The fruit itself is used in many industries not only as food but for other uses as well (Reddy, 2015). The energy industry has also seen the potential of the coconut as the coco-diesel was created as an alternative to the fossil fueled oils the Philippines import (Ganiron, 2013). Aside from its ornamental use, the shell has been powdered and used as glues and its charcoal form was used as activated carbon and used as a filter material for masks and air-conditioning systems (Esquenazi, 2002). In the construction

industry, the husk is used as a mat in preventing the erosion of soils. Boards are created from the husk of the coconut by acquiring the fibers from the husk (Babel, 2004). Figure 1.2 shows coconut production in Asia Pacific region in 2014, by country (in thousand tons).

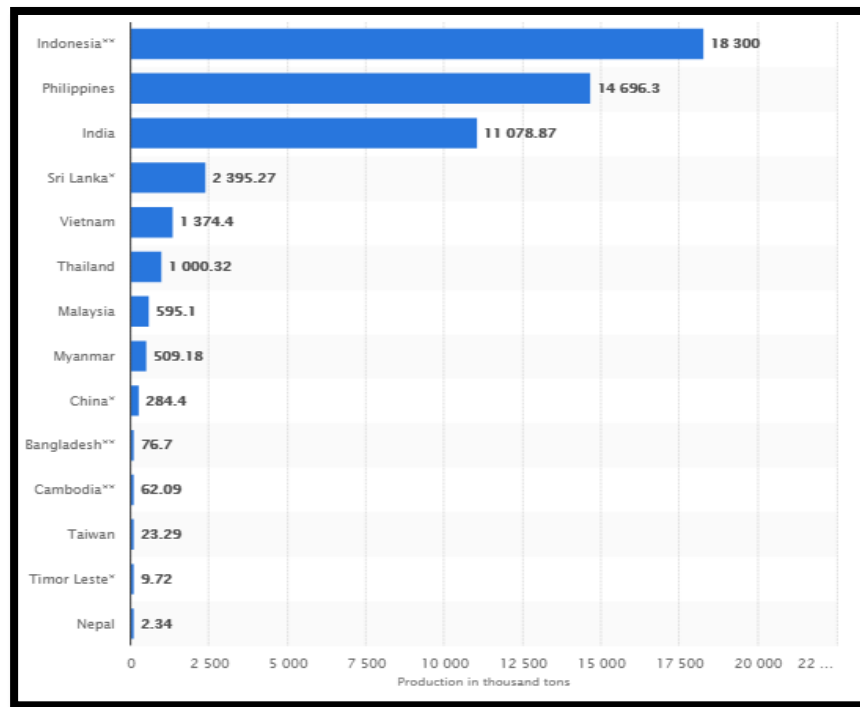


Figure 1.2: Coconut production in Asia Pacific region in 2014, by country (in thousand tons)

Source: Ganiron (2013)

Construction on soft ground area or as known as soft clay soil is a great challenge in the field of geotechnical engineering and always been a challenging task for engineers in Malaysia. The construction over soft clay soil is increasing due to lack of suitable land for infrastructures and other developments (Chin, 2005). Thus many engineering problems in the form of slope instability, bearing capacity failure or excessive settlement could occur either during or after the construction phase due to low shear strength and high compressibility of this soil. Instability of the ground during construction works had caused delay and cost overrun in completion of the project in Selangor, whereas occurrence of continuous post construction settlement had affected the integrity and serviceability of the building in Sabah (Khairul et al., 2006). Expansive soils causing more damage to structures, particularly light buildings and pavements, than any other

REFERENCES

- Achaw, O. W., & Afrane, G. (2008). The evolution of the pore structure of coconut shells during the preparation of coconut shell-based activated carbons. *Microporous and mesoporous materials*, 112(1), 284-290
- Ali, K, Shahu, J.T, Sharma, K. (2010). Behaviour of Reinforced Stone Columns in Soft Soils : An Experimental Study. *Indian Geotechnical Conference*, (1975), 625–628.
- Arathy, V. B., Jery, C., Raj, J., Lekshmi, V. S., & Chacko, A. (2015). Effect of Coconut Shell Powder on the Strength of Soil. *International Journal of Management, Information Technology and Engineering*, 3(2), 35–40.
- Aw, P. C. (1986). Geology and exploitation of kaolin deposits in the Bidor area, Peninsular Malaysia., (August).
- Balasubramaniam, A. S. & Brenner R. P. (1981) Consolidation and Settlement of Soft Clay, *Soft Clay Engineering (Development in Geotechnical Engineering)*, Elsevier Scientific Publishing Company, 20 481 – 527.
- Beena, K. S. (2010). Ground Improvement using Stone Columns. *International Conferences on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics.*, 1–7. Retrieved from internal-pdf://77.239.98.123/Ground Improvement using Stone Columns.pdf
- Cabe, Bryan, A. (2007). Ground Improvement Using The Vibro-Stone Column Technique, Department of Civil Engineering, National University of Ireland, Galway.
- Castro, J. (2017). Geotextiles and Geomembranes Groups of encased stone columns : Influence of column length and arrangement. *Geotextiles and Geomembranes*, 45(2), 68–80. <https://doi.org/10.1016/j.geotexmem.2016.12.001>
- Chin, I. (2005). Embankment over Soft Clay–Design and Construction Control. *Geotechnical Engineering*, (May), 1–15. Retrieved from http://www.gnpgeo.com.my/download/publication/2000_07.pdf
- Damoerin, D., Prakoso, W. A., & Utami, Y. (2015). Improving shear strength of clay by using cement column reinforcement under consolidated undrained test. *International Journal of Technology*, 6(4), 709–717. <https://doi.org/10.14716/ijtech.v6i4.1206>
- Das. (2015). Variation in the Properties of Kaolinite By Varying the Percenatge of Ground Granulated Blast Furnace Slag (Ggbs) and Lime Added in Kaolinite Variation in the Properties of Kaolinite By Varying the Percenatge of Ground Granulated Blast Furnace Slag (Gg. *International Journal of Electronics, Electrical and Computational System*, 4(August), 260–266.
- Deshpandey, P.M. & Vyas, A.V. (1996). Interactive encased stone column foundation. Sixth international conference and exhibition on

piling and deep foundation, DFI'96, ISSMFE, Bombay, ppl-19

- Devdatt, S., Shikha, R., Saxena, A. K., & Jha, A. K. (2015). Soil Stabilization Using Coconut Coir Fibre. *International Journal for Research in Applied Science & Engineering Technology*, 3(9), 305–309.
- Esquenazi, D., Wigg, M. D., Miranda, M. M., Rodrigues, H. M., Tostes, J. B., Rozental, S., & Alviano, C. S. (2002). Antimicrobial and antiviral activities of polyphenolics from *Cocos nucifera* Linn.(Palmae) husk fiber extract. *Research in microbiology*, 153(10), 647-652
- Fakher, A., Jones, C.J.F.P., & Clarke, B.G. (1999). Yield Stress of Super Soft Clays. *Journal of Geotechnical and Geoenvironmental Engineering*. Vol. 25. No. 6. 499-509.
- Food and Agriculture Organization FAO Statistics 2007. Retrieved from International Journal of Civil Engineering and Technology (IJCIET), ISSN 0976 – 6308 (Print), ISSN 0976 – 6316(Online), Volume 6, Issue 3, March (2015), pp. 42-61
- Ganiron, T. U. (2013). Sustainable management of waste coconut shells as aggregates in concrete mixture. *Journal of Engineering Science and Technology Review*, 6(5), 7–14.
- Gunasekaran, K., Kumar, P. S., & Lakshmi pathy, M. (2011). Mechanical and bond properties of coconut shell concrete. *Construction and Building Materials*, 25(1), 92–98. <https://doi.org/10.1016/j.conbuildmat.2010.06.053>
- Gunasekaran, K., Annadurai, R. and Kumar, P. (2011). Long Term Study on Compressive and Bond Strength of Coconut Shell Aggregate
- Gunasekaran, K., Pennarasi, G., Soumya, S., & Shruti, L. (2017). All-in-One About a Momentous Review Study on Coconut Shell As Coarse Aggregate in Concrete, 8(3), 1049–1060.
- Huat B. B. K., Othman K., & Jaafar, A. A. (1995) Geotechnical Properties of Malaysia Marine Clays, *Journal – Institution of Engineers Malaysia*.
- Hughes, J.M.O., & Withers, N.J. (1975). Reinforcing of soft cohesion soils with stone columns. *Ground Engineering*, vol. 7, No. 3 pp. 42-42 and pp. 47-49.
- Ismail, I. (2014). Malaysians producing more solid waste than before | Malaysia | Malay Mail Online. *The Malay Mail*. Retrieved from <http://www.themalaymailonline.com/malaysia/article/malaysians-producing-more-solid-waste-than-before>
- Jenny, H. (1980). *The Soil Resource, Origin and Behaviour*. New York: Springer-Verlag.
- Froese, K. (2004). Bulk density, soil strength, and soil disturbance impacts from a cut-to-length harvest operation in north central Idaho. M.Sc. thesis, Univ. Of Idaho.

- Keerthika, B., Umayavalli, M., Jeyalalitha, T., & Krishnaveni, N. (2016). Coconut shell powder as cost effective filler in copolymer of acrylonitrile and butadiene rubber. *Ecotoxicology and Environmental Safety*, 130, 1–3.
<https://doi.org/10.1016/j.ecoenv.2016.03.022>
- Khairul, N., Lee, C., Phuai, P., & Saiful, A. (2006). The Correlations Between Chemical and Index Properties for Soft Clay of Peninsular Malaysia. *Technology and Innovation for Sustainable Development Conference (TISD2006)*, (January 2006), 152–161.
- Malarvizhi, S. N., & Ilamparuthi, K. (2002). Load versus Settlement of Clay bed stabilized with Stone & Reinforced Stone Column, Anna University.
- Mani, K., & Nigee, K. (2013). Focus on Ground Improvement. *International Journal of Innovative Research in Science, Engineering and Technology*, 2(11), 6451–6456.
Retrieved from www.ijirset.com
- Mitra, S., & Chatopadhyay, B. C. (1999). Stone Columns and Design limitations. Proc. Of Indian Geotechnical Conference held at Calcutta, 201–205.
- Mitchel, J. K., & Huber, T. R. (1985). Performance of a stone column foundation. *Journal of Geotechnical Engineering*, Vol.111, No.2, ASCE.
- Mohamad, N. O., Razali, C. E., Hadi, A. A. A., Som, P. P., Eng, B. C., Rusli, M. B., & Mohamad, F. R. (2016). Challenges in Construction Over Soft Soil - Case Studies in Malaysia. *IOP Conference Series: Materials Science and Engineering*, 136, 12002.
<https://doi.org/10.1088/1757-899X/136/1/012002>
- Mohd Yusoff, S. A. N., Bakar, I., Wijeyesekera, D. C., Zainorabidin, A., & Madun, A. (2015). Comparison of Geotechnical Properties of Laterite, Kaolin and Peat. *Applied Mechanics and Materials*, 773–774, 1438–1442.
<https://doi.org/10.4028/www.scientific.net/AMM.773-774.1438>
- Mokhtari, M., & Kalantar, B. (2012). Soft soil stabilization using stone columns-a review. *Electronic Journal of Geotechnical Engineering*, 17 J, 1659–1666.
- Mousavi, S., & Wong, L. S. (2015). Mechanical behavior of compacted and stabilized clay with kaolin and cement. *Jordan Journal of Civil Engineering*, 9(4), 477–486.
- Muhmed, A., & Wanatowski, D. (2013). Effect of Lime Stabilisation on the Strength and Microstructure of Clay. *IOSR Journal of Mechanical and Civil Engineering*, 6(3), 2320–334. <https://doi.org/10.6088/ijes.2013030600005>
- Neville, A.M. (2000). Properties of Concrete. 4th ed. (low-price ed.). Pearson Education Asia Publ., England, produced by Longman Malaysi
- Ooi, J. B. (1963). Land, People and Economy in Peninsular Malaysia. Longman Group Ltd., pp 14 – 17.

- Oluremi, J. R. (2012). Stabilization of Poor Lateritic Soils with Coconut Husk Ash. *International Journal of Engineering Research and Technology*, (April 2014), 2278–181.
- Pauze, M., & Mohamad, B. I. N. (2016). Integrated solid waste management : challenge and future.
- Pivarč, J. (2011). Stone Columns - Determination of the soil improvement factor. *Slovak Journal of Civil Engineering*, XIX(3), 17–21. <https://doi.org/10.2478/v10189-011-0014-z>
- Prasad, N. & Acharya, S. (2006). Development and Characterization Of Metal Matrix Composite Using Red Mud an Industrial Waste For Wear Resistant Applications. Development.
- Reddy, N. & Yang, Y. (2015). Coconut Husk Fibers. *Innovative Biofibers from Renewable Resources* (pp. 31-34). Springer Berlin Heidelberg.
- Rudrabir, G. & Kashliwal A. (2008) Ground Improvement Techniques – with a Focused Study on Stone Column, Dept. of Civil Engineering, VIT University.
- Rusbintardjo, G., Hainin, M. R., & Yusoff, N. I. M. (2014). Fundamental and Rheological Properties Of Oil Palm Fruit Ash Modified Bitumen. *Construction and Building Materials*. 49: 702-711.
- Shanker, K. & Shroff, A.V. (1997). Experimental Studies on Floated Stone Column in Soft Kaolinite Clay. *Proc. Of Indian Geotechnical Conference held at Vadodara*, pp. 265-268.
- Sreenivasan, J., & Govindan, M. (2012). Solid Waste Management in Malaysia – A Move Towards Sustainability, 2005(April 2005).
- Ting, T. L., Jaya, R. P., Hassan, N. A., Yaacob, H., Jayanti, D. S., & Ariffin, M. A. M. (2016). A review of chemical and physical properties of coconut shell in asphalt mixture. *Jurnal Teknologi*, 78(4), 85–89. <https://doi.org/10.11113/jt.v78.8002>
- Ucol-Ganiron Jr, T. (2013). Recycling of Waste Coconut Shells as Substitute for Aggregates in Mix Proportioning of Concrete Hollow Blocks. *WSEAS TRANSACTIONS on ENVIRONMENT and DEVELOPMENT*, 9(4), 290–300.
- Varghese, S., Kuriakose, B., Thomas, S. & Koshy, A. (1991). Studies on Natural Rubbershort Sisal Fiber Composites. *Indian J. Nat. Rubb. Res.* 4: 55.
- Wada Isah, B. (2014). Effect of Coconut Shell Ash on Properties of Fired Clay Brick. *Journal of Civil Engineering and Environmental Technology Print*, 1(6), 2349–8404. Retrieved from <http://www.krishisanskriti.org/jceet.html>

- White, W. A. (1987): Atterberg plastic limits of clay minerals, *American Mineralogist*, 34, 508–512.
- www.moa.gov.my/documents/10157/010b6921-c643-421d-aef1-29ae379f6f85. Agro Food Statistics 2014, Ministry of Agriculture and Agro-Based Industry Malaysia. Agricultural Consumption Per Capita (2013-2014).